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# Design of Survey X-Ray Spectrometer for NIF, NSS

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## Disclaimer

# Design of Survey X-Ray Spectrometer for NIF, "NSS"

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Lawrence Livermore National Laboratory • National Ignition Facility & Photon Science

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# X-Ray Spectrometer Overview

- X-Ray Spectrometers have been successfully deployed, at many facilities including OMEGA and NIF, to study emission and absorption spectra of materials.

- Function:  High resolution spectra covering the 6 – 365 keV in a single shot
  - NIF is currently limited to 5.8 – 16.5 keV

- High energy density source development applications
  - Complimentary instrument on NIF is FFLEX

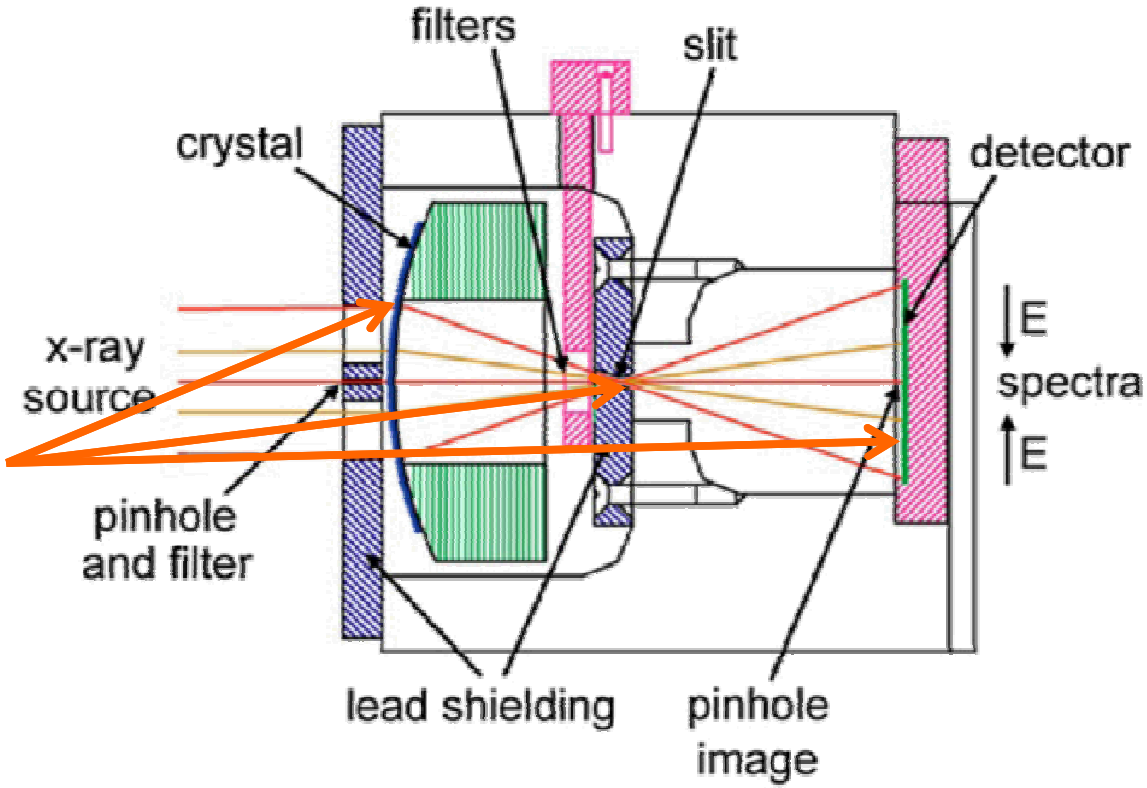
- The NSS design is based on spectrometers successfully deployed at LLE on the OMEGA and EP lasers.
  - Cauchois Type Spectrometer
  - Two identical channels
  - Cylindrically bent transmission crystals

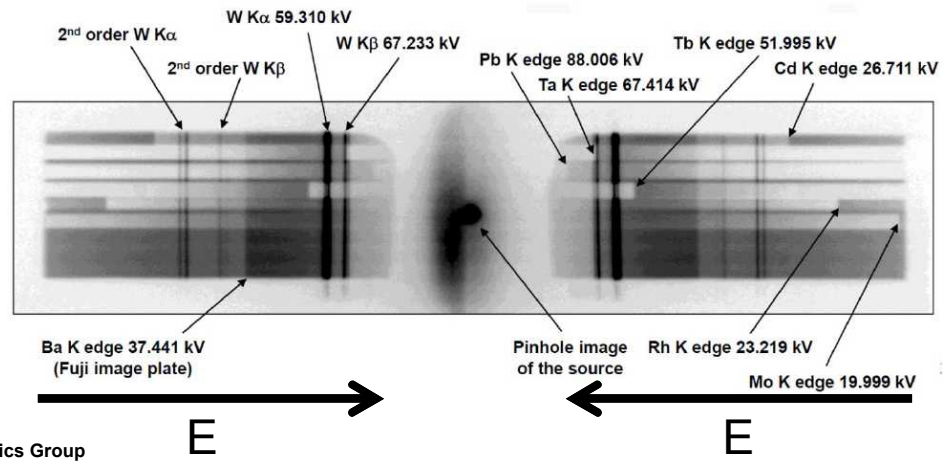
# Cauchois Type Spectrometer Design

- All X-Rays of a given energy, from an extended source, are focused on the Rowland circle

- Spectrometer consists of
  - Cylindrically bent transmission crystals
  - Slit Aperture
  - Detector placed on the Rowland Circle

- Rays diverging from the source are diffracted by the crystal and pass through the slit to the detector, producing two spectra that are symmetric about the axis

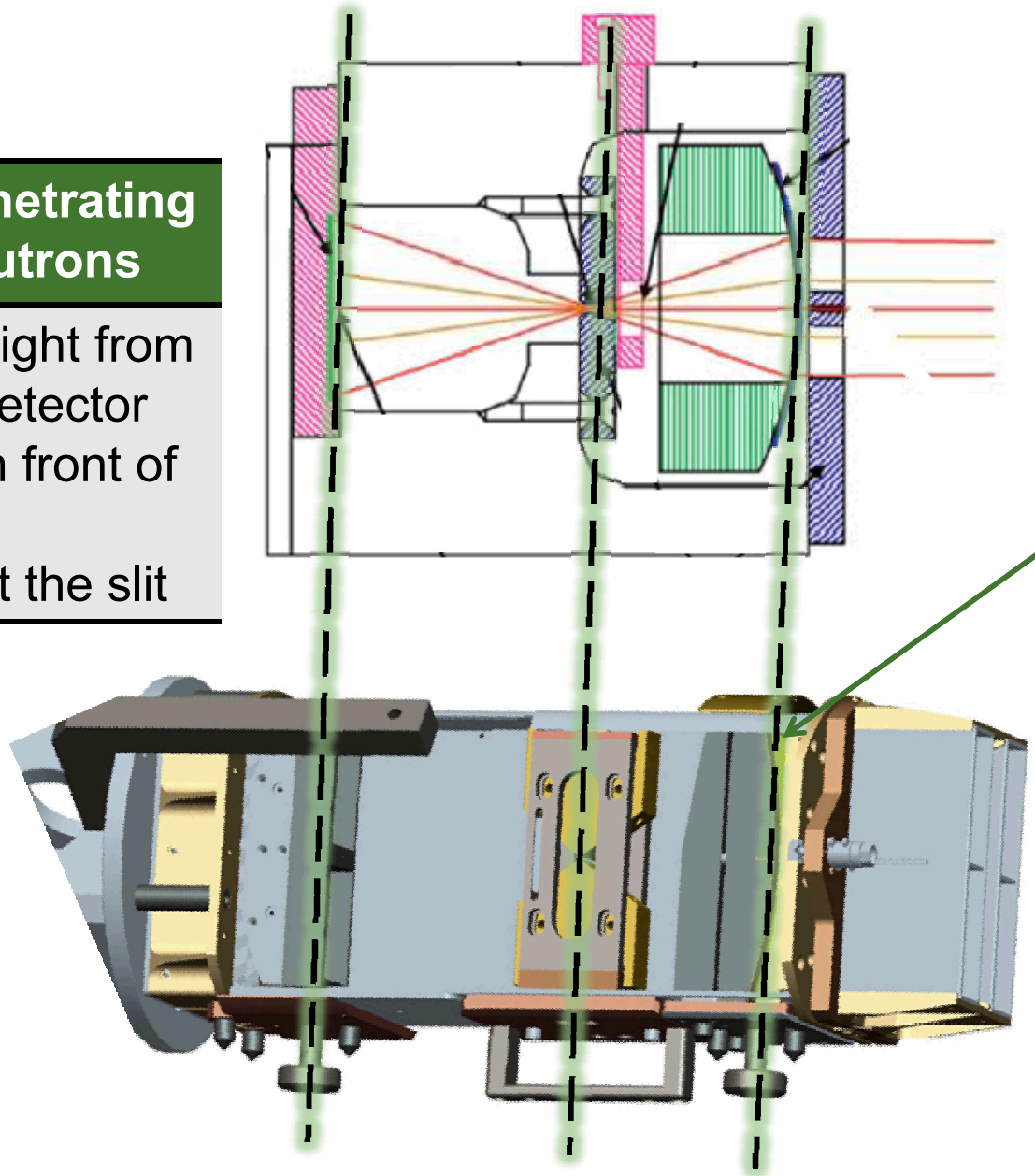


# Implementation on NIF

## Effects of Penetrating Radiation Neutrons

- No line of sight from source to detector
- Shielding in front of crystal
- Shielding at the slit



## Larger Source to crystal standoff distance

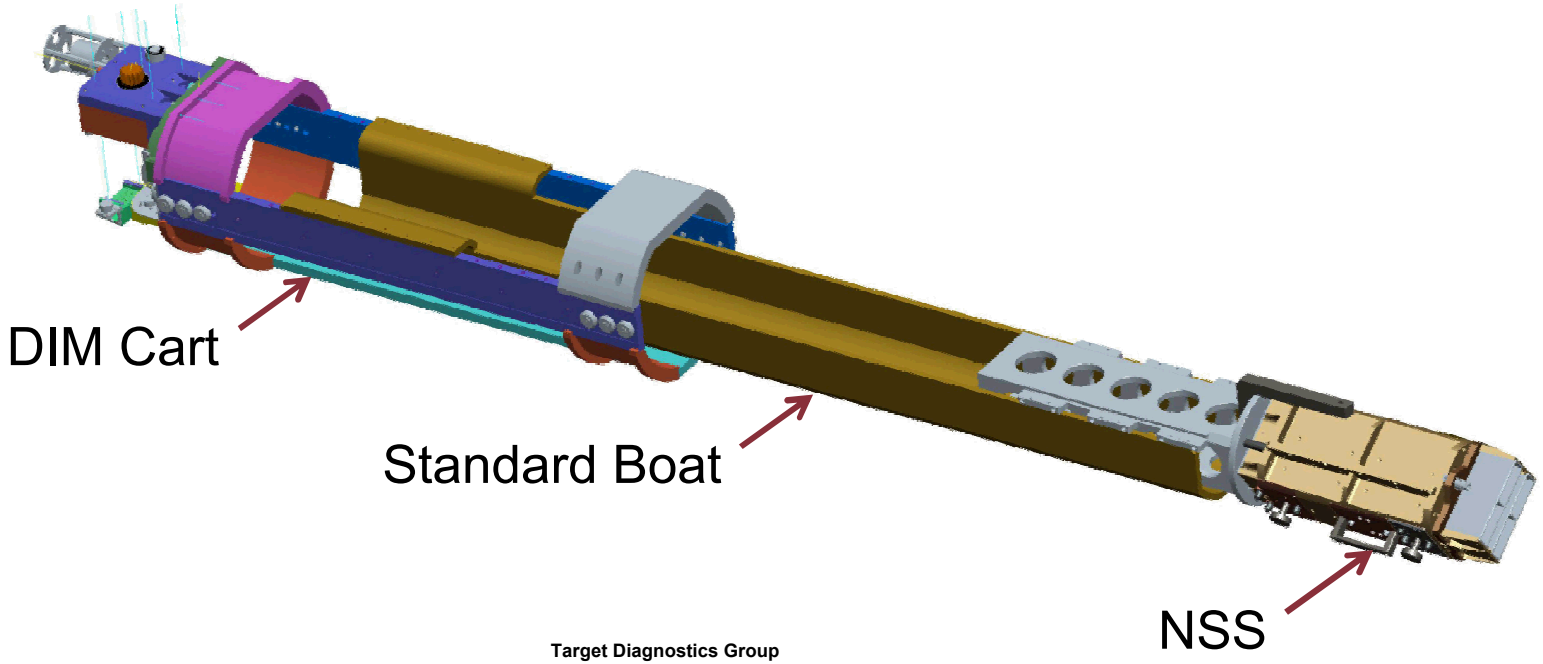
- Longer crystals necessary to achieve wide range of Bragg angles and energy coverage
- Unique alignment hardware / plan

# Implementation on NIF, cont.

| Phased Approach to Implementation on NIF | |
|---|---|
| Phase A | Diagnostic Instrument Manipulator (DIM) Based Instrument |
| Phase B | Custom Manipulator on NIF |

# NSS on NIF

- **NSS Function:**
  - **High resolution spectra covering the x-ray/gamma-ray range 6-365 keV**
- **NSS Features:**
  - **DIM (Diagnostic Instrument Manipulator) and TIM (Ten Inch Manipulator) compatible, 3 m standoff distance from TCC (Target Chamber Center).**
  - **Two spectrometer channels with identical geometry and interchangeable crystals.**
    - **Five interchangeable crystals cover 6 – 365 keV in 1st order with >200 resolving power, 511 keV in 2nd order.**
  - **IPs (Image Plates) for Data Collection**

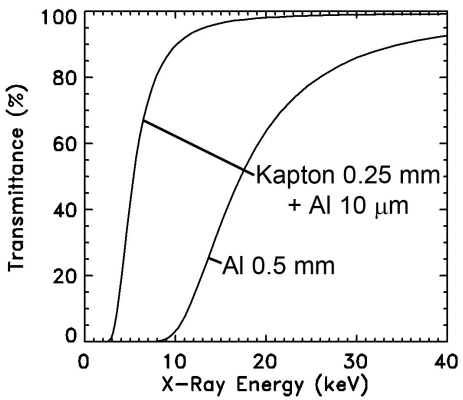


# NSS Crystals: Discrete Energy Ranges and K Edge Filters

| NSS crystal type | #1 | #2 | #3 | #4 | #5 |
|---|---|---|---|---|---|
| Quartz diffracting planes | (100) | (101) | (203) | (502) | (550) |
| Number provided | 6 | 5 | 4 | 4 | 4 |
| Lattice spacing 2d (nm) | 0.8512 | 0.6684 | 0.2750 | 0.1624 | 0.0983 |
| Energy coverage (keV) | 6 - 49 | 8 - 63 | 19 - 152 | 32 - 260 | 53 - 400 |
| Crystal thickness (mm) | 0.08-0.10 | 0.08-0.10 | 0.25 | 0.25 | 0.50 |
| Relative diffraction efficiency | 30 | 100 | 40 | 13 | 6 |
| Perpendicular planes | (001) | (1-20) | (1-20) | (1-20) | (001) |
| Blast window material | Kapton/Al | Kapton/Al | Al | Al | Al |
| Blast window thickness | 0.25 mm/10 μm | 0.25 mm/10 μm | 0.5 mm | 0.5 mm | 0.5 mm |
| K edge filter materials | Mn, Mo | Cu, Ho | Ag, Au | Ho, Pb | Hf, U |
| Filter thicknesses (μm) | 10, 100 | 10, 100 | 100, 150 | 100, 150 | 100, 200 |
| Filter K edge energies (keV) | 6.538, 20.000 | 8.980, 55.620 | 25.516, 80.721 | 55.620, 88.006 | 65.316, 115.601 |
| Image plate Ba K edge (keV) | 37.452 | 37.452 | 37.452 | 37.452 | |

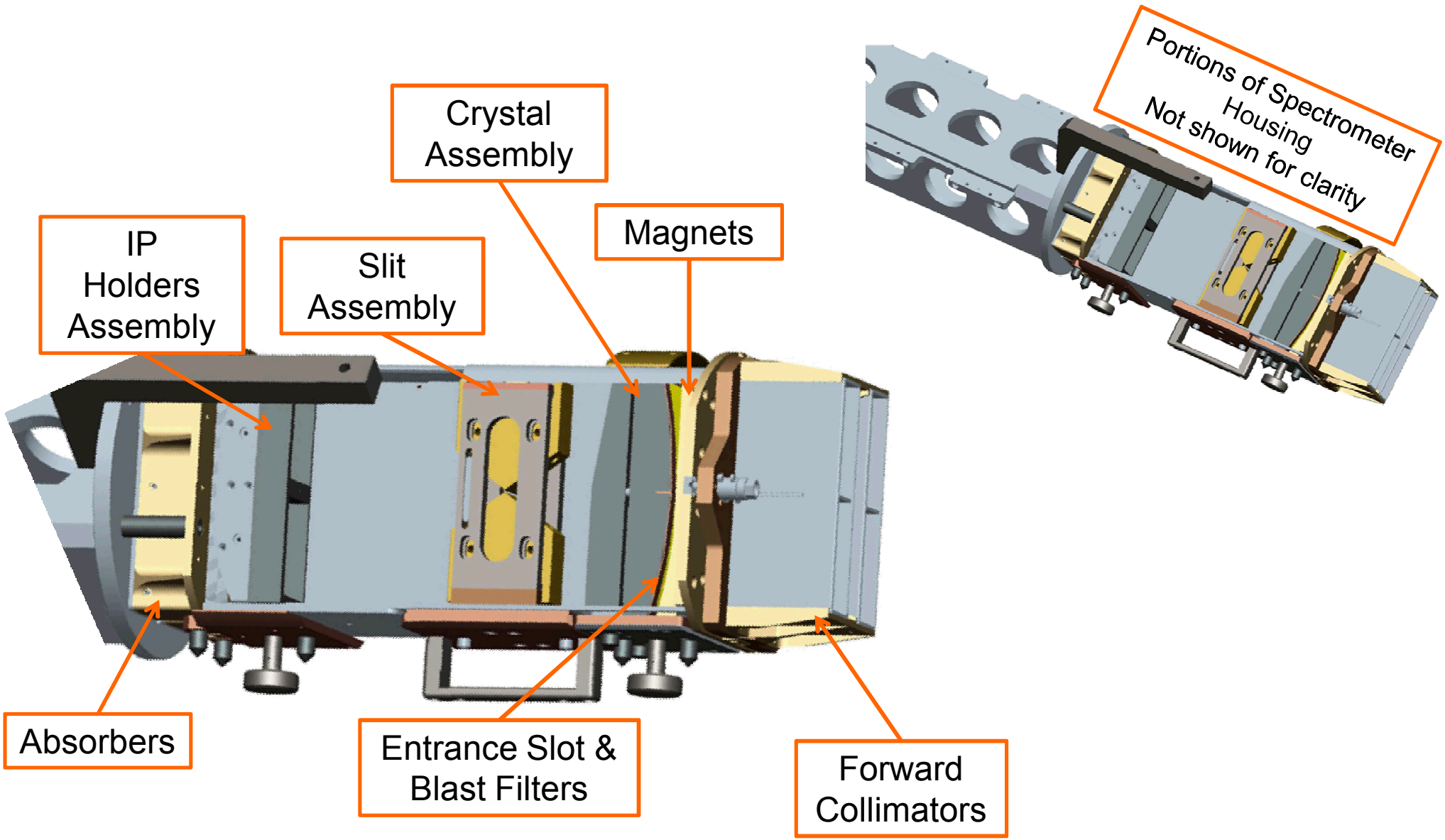
Thickness & Transmittance:

*Blast Window size is 41.3 mm x 84.1 mm.*

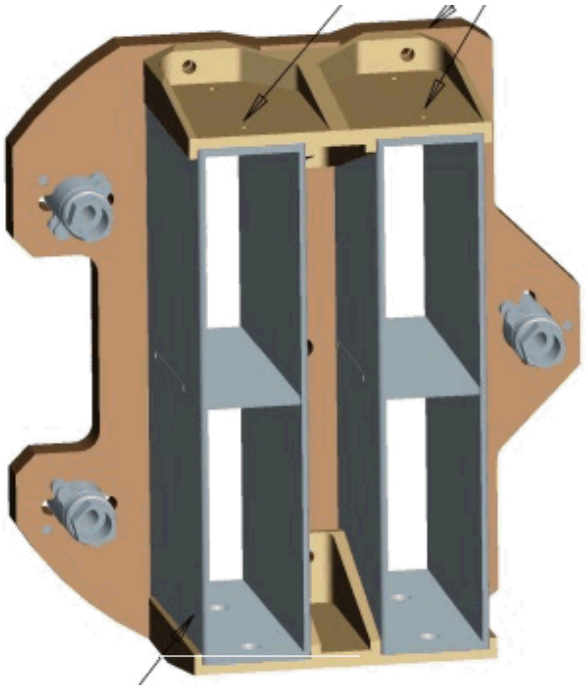


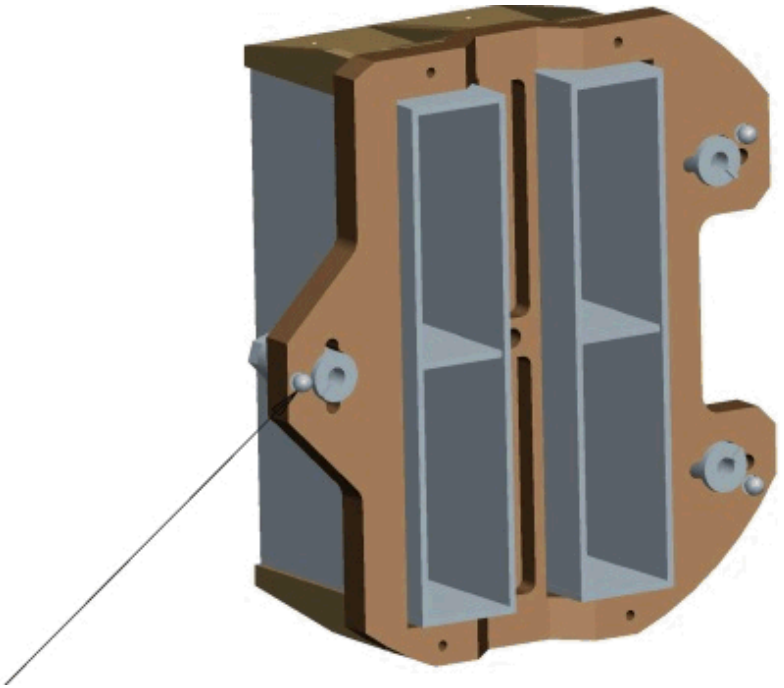
# Overview of NSS Hardware

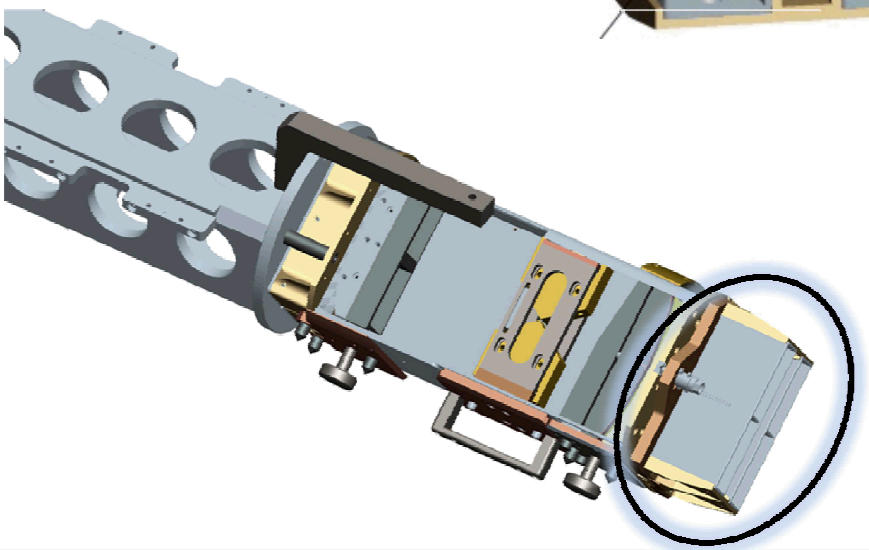
# Overview of NSS Hardware, cont.



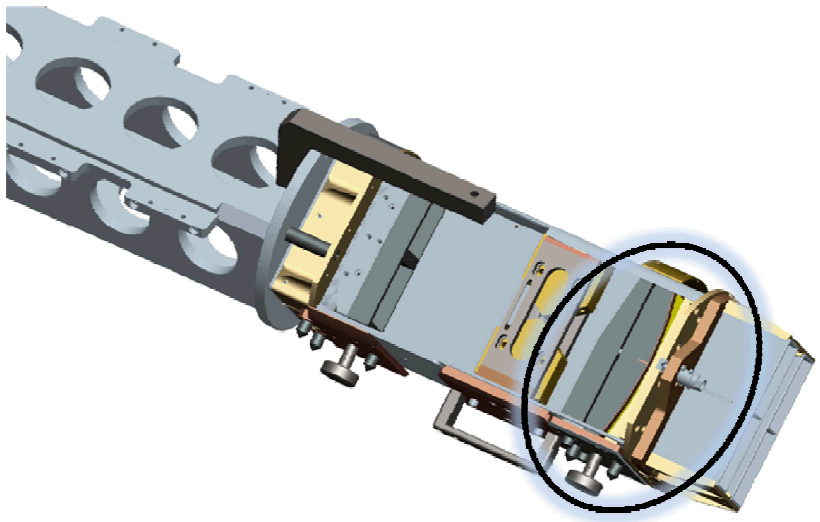
# NSS Entrance Collimator Sub-Assembly

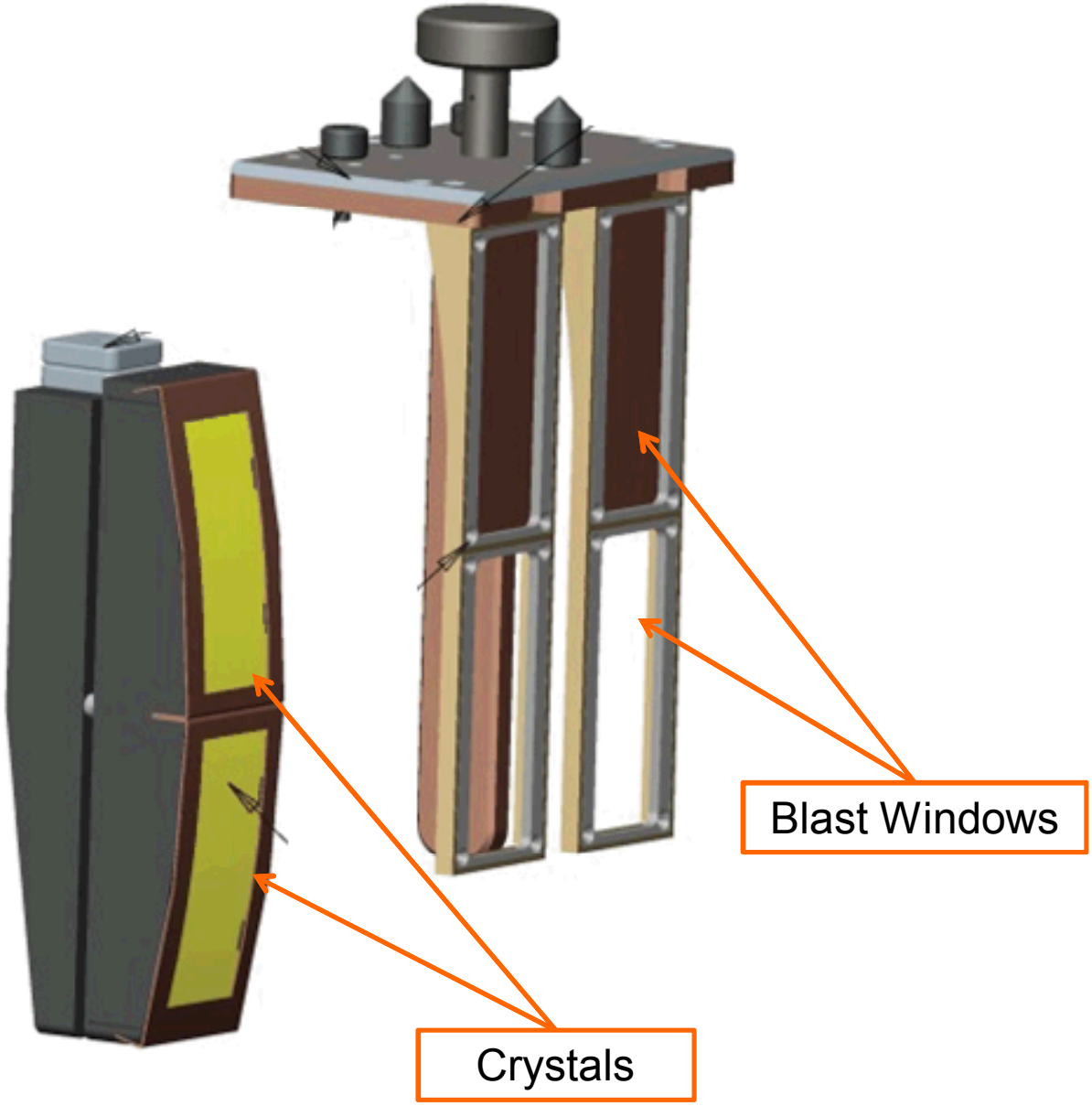






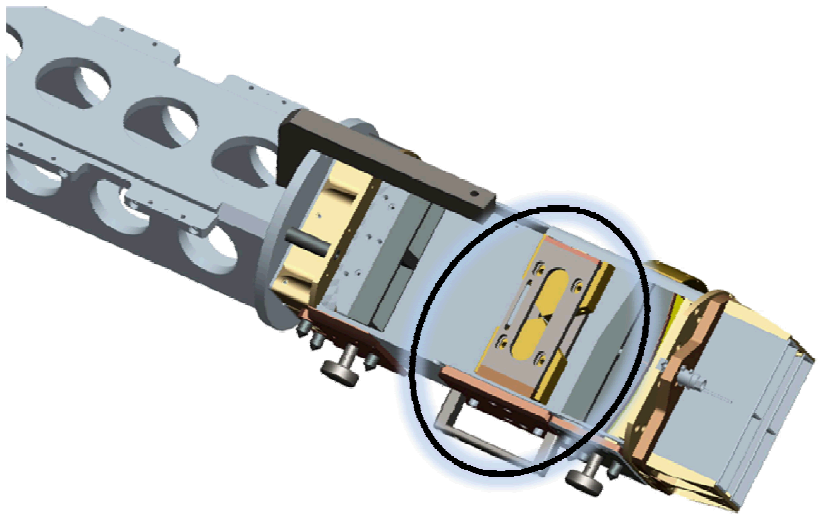
# NSS Removable Crystal Module

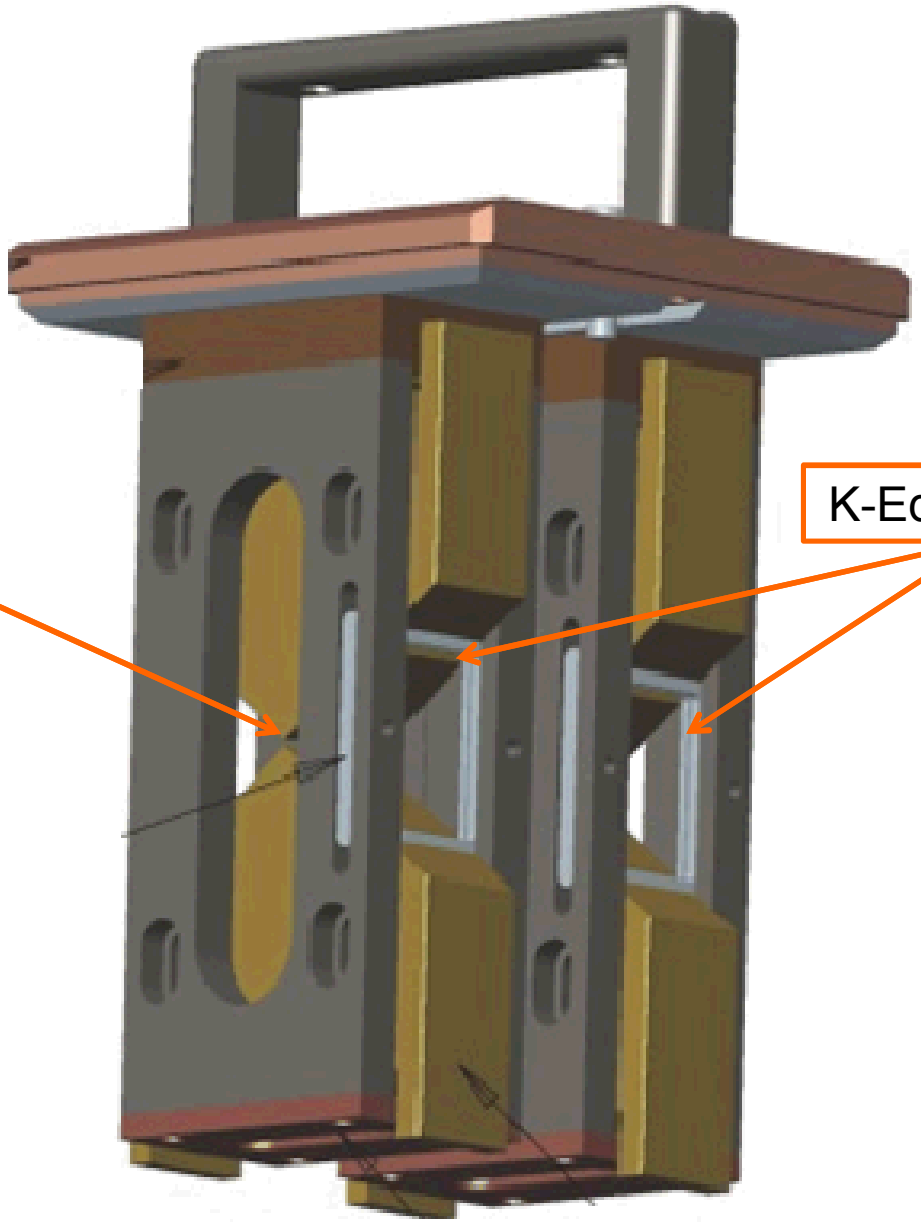




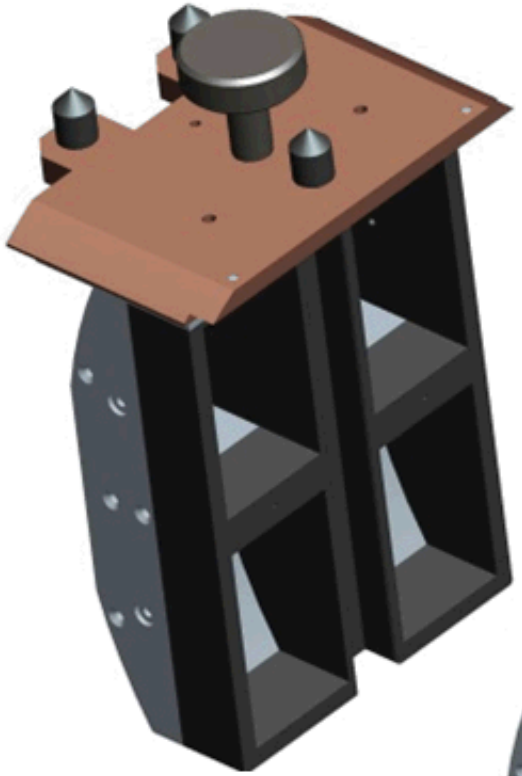

*Blast Window size is 41.3 mm x 84.1 mm*

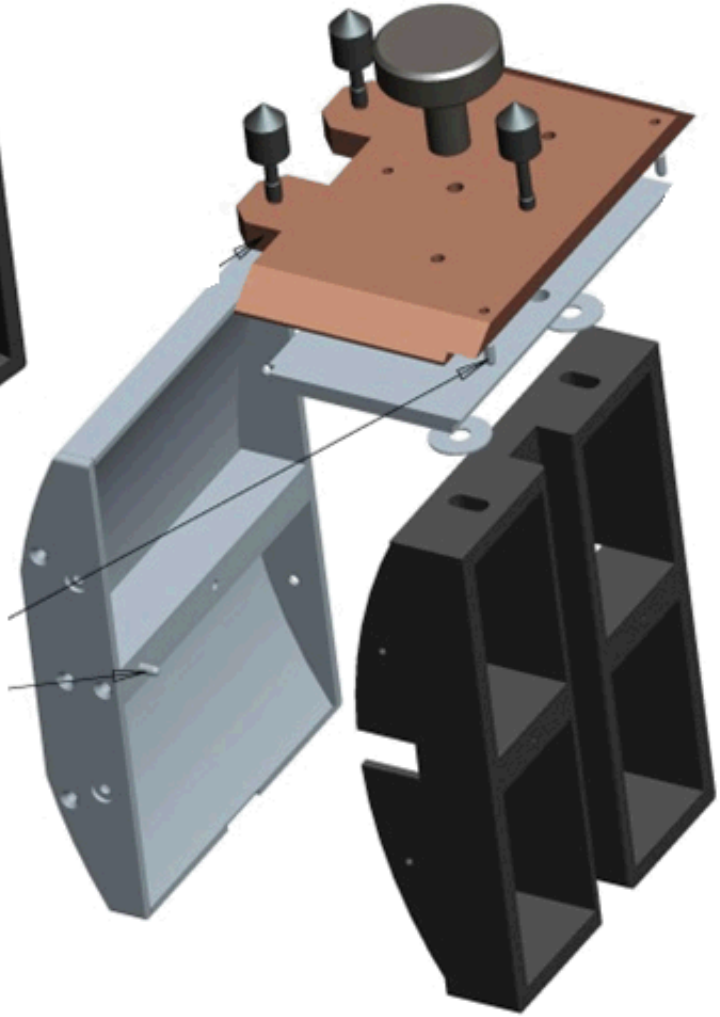
# NSS Removable Crossover Slit Module

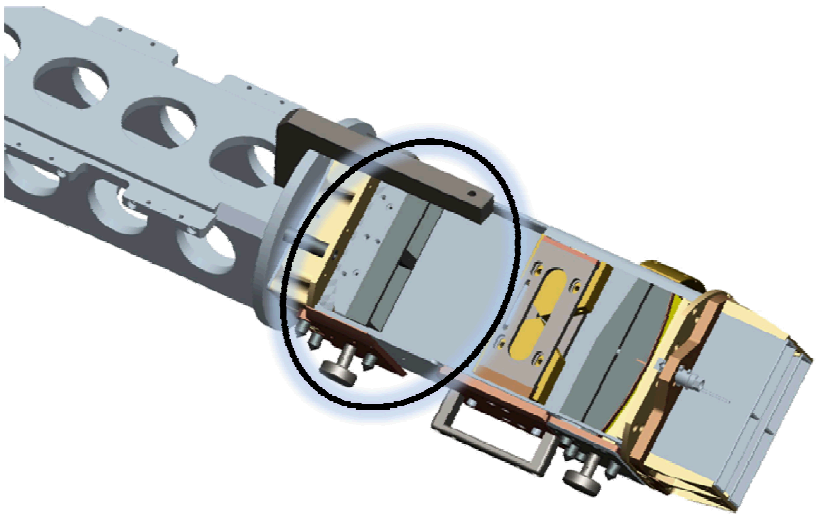




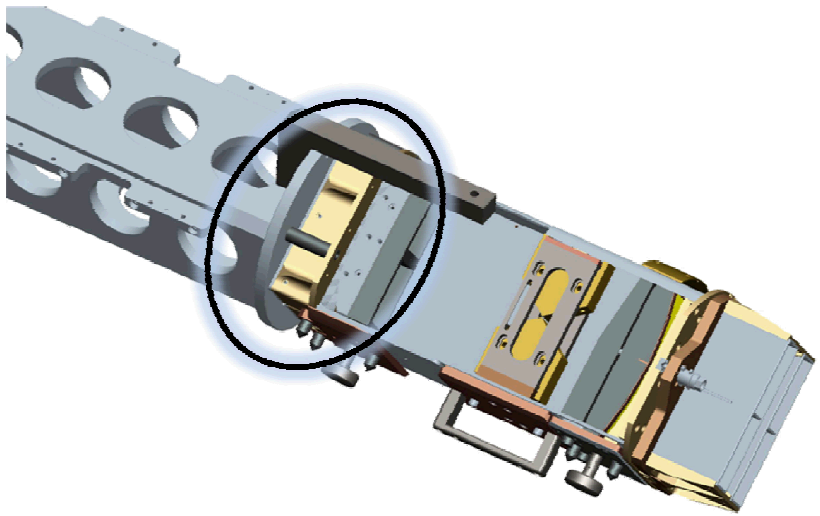
# NSS Removable IP Module

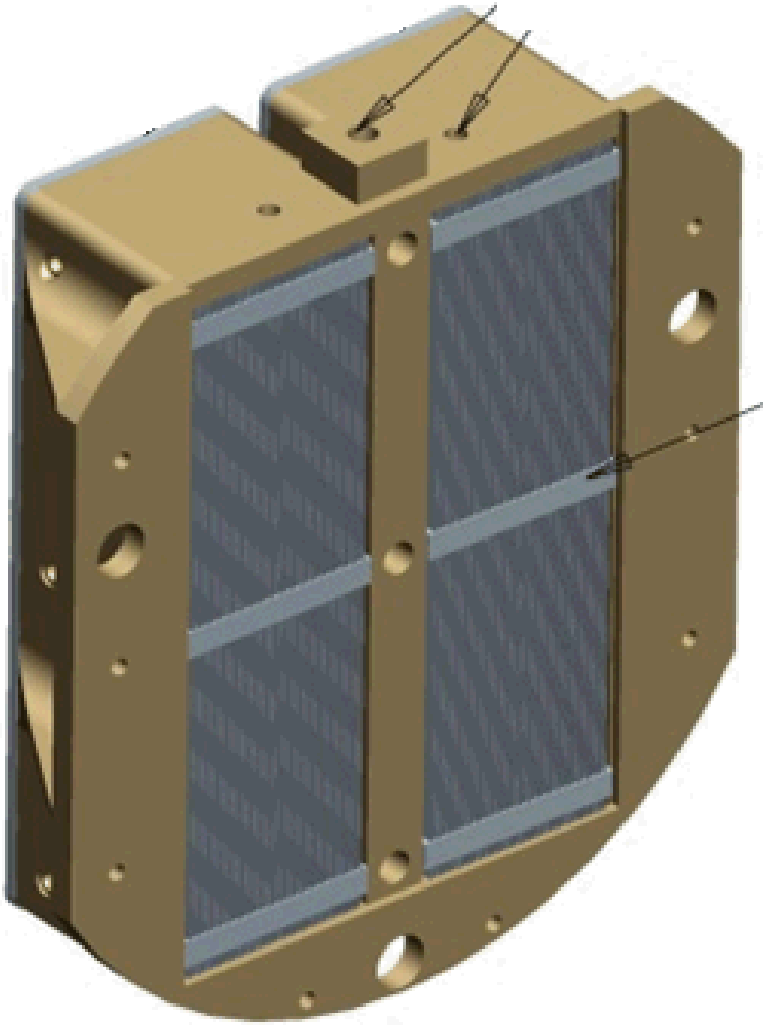




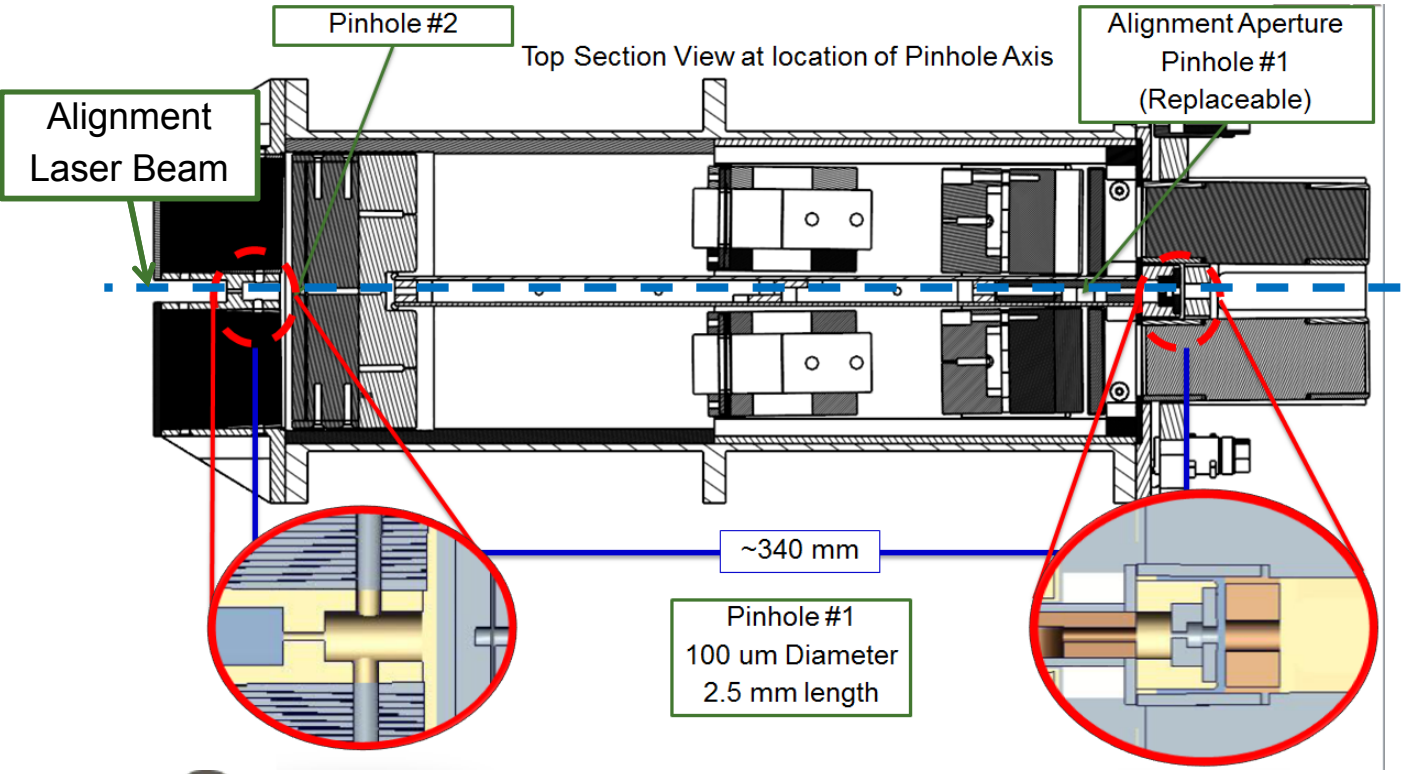


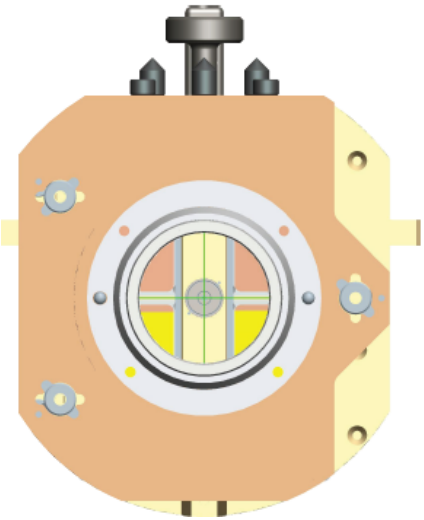
# NSS Absorber Sub-Assembly



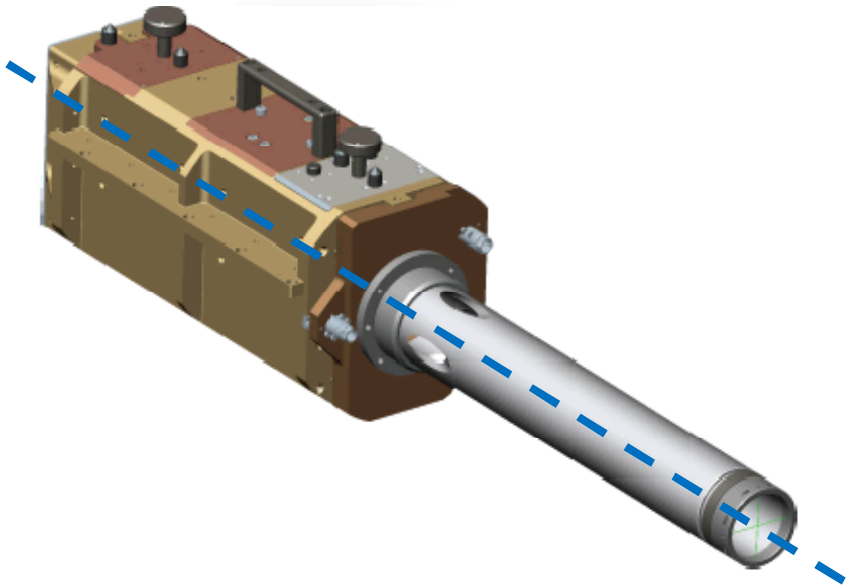


# NSS DIM Fixture & Alignment Fixture Assemblies



View from TCC

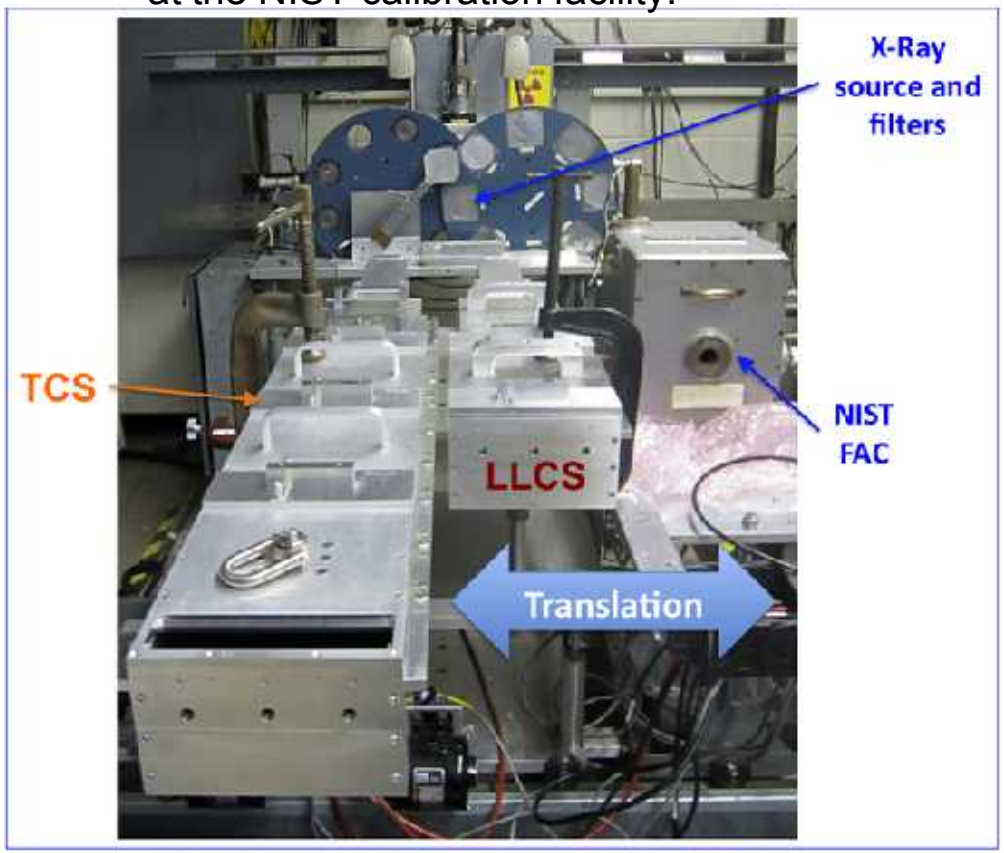


| | |
|---|---|
| **Alignment & Pointing** | **± 0.1 mm in X & Y at the slit**<br>**3000 mm (detector to TCC) stand-off**<br>**± 5 cm in Z** |
| FOV | ± 3 mm in X & Y (at TCC) |
| Opposed Port Alignment System (OPAS) is used to align NSS | |

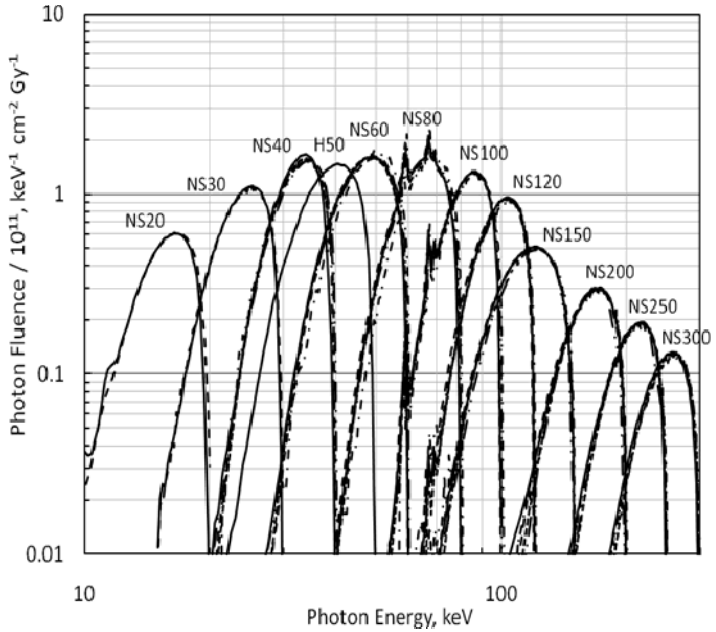
# Calibration Plan

**The NSS end-to-end sensitivity can be measured at the NIST calibration facility**

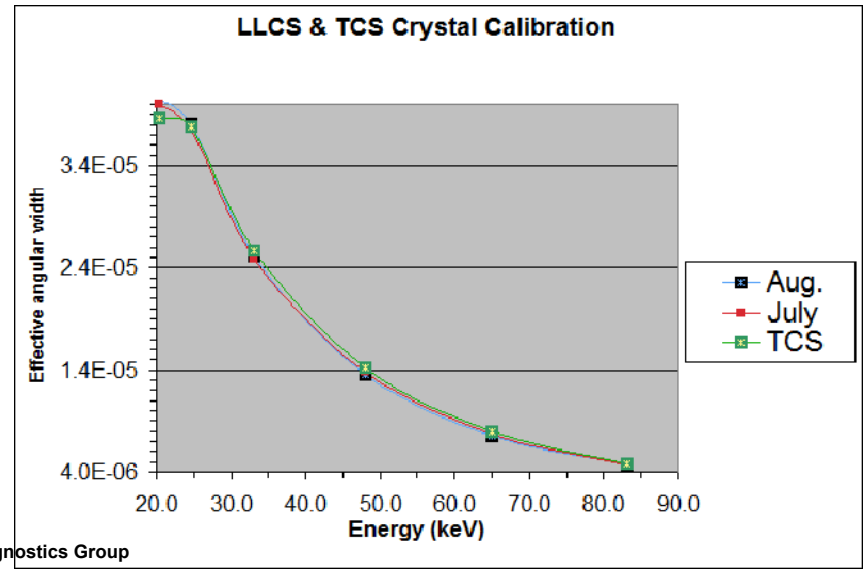
Two spectrometers (TCS and LLCS) at the NIST calibration facility:




Absolutely calibrated x-ray fluences:




Calibration of the crystal integrated reflectivity:



# NSS Project Status

| | Phase | Description |
|---|---|---|
| Phase A | Phase I | Conceptual Design and Review |
| | Phase IIA | NSS and DIM/TIM Mounting Preliminary Design |
| | Phase IIB | Preliminary Design Details and Review |
| | Phase III | Final Design Details and Review |
| | Phase IV | Build Hardware |
| | Phase V | Calibration |
| Phase B | Phase VI | Custom Manipulator for NIF |

- NSS will be ready for NIF shots 4th Quarter of FY14
- NSS is expected to meet the defined instruments requirements.
- NSS will add the ability to record a high resolution broad band spectrum


NIF